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EFFECT OF LOADING STAGE ON PEAT COMPRESSION AND DEFLECTION OF BAMBOO GRID WITH CONCRETE PILE

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ABSTRACT: Improvement of peat compression and increasing the bearing capacity can be achieved with the embankment load as preloading. The embankment on peat soil has problems such as excessive settlement, horizontal movement, and differential settlement. The stability of embankment is maintained with the installation of the reinforcement system, but the time factor and duration of loading can affect the stability of embankment and excess settlement. It is necessary to study the loading stages that can maximize compression and minimize deflection so that stability can be maintained. The embankment load test was performed on peat soil reinforced with bamboo grid and concrete piles. The model test in the laboratory used the test box measuring 120 cm x 90 cm x 90 cm with a height of the peat soil of 50 cm. The embankment load was distinguished based on the stage and duration of loading. The results showed that multiple stages is better than the single-stage because settlement changes are relatively smaller than the other. The longer load duration provides the opportunity to consolidate the peat layer so that the bearing capacity and the modulus of subgrade reaction increases. The good stage load is obtained in three stages with the addition of the embankment load of 3.02 kPa or 1/3 of the total load every 2 days or 1/3 of the total duration of the load. At this stage and duration, the peat compression and the deflection of reinforcement are smaller than the others.

Keywords: Loading stage, Peat, Embankment, Bamboo grid, Pile, Loading stage, Compression, Deflection

1. INTRODUCTION

High compression and low undrained shear strength are the general properties of peat soil when subjected to imposed loads [1]. Fibrous peat soil has high permeability and reinforcement of fiber when subjected to the process of loading so that the soil does not show the failure mechanisms [2]. But it has to be understood that peat soil, including soft soil types, has stability problems.

According to Waruwu et al., [3], peat compression and bearing capacity can be improved by a long embankment load. An improved method of peat soil properties can be done by preloading the form of an additional embankment load. Preloading can speed up compression and increase the bearing capacity of peat soil so that the stability of the embankment is maintained, and it constitutes a necessary reinforcement system. The embankment is hard to be deformed and settled when the ground is reinforced by a sheet pile with nailing [4].

The embankment with thin layers requires more time, whereas thick embankment has problems with the excessive settlement, horizontal movement, and differential settlement. The embankment on peat soils is obtained safely by the installation of piles. The installation of piles to hard soil is more relevant for use in organic soils such as peat than to the stabilization method [5]. Reinforcement contributes to the increasing stability of the embankment, while reinforcement and shear strength of peat will withstand the lateral forces [6].

According to Liu et al. [7], piles under embankment have several advantages. They need a shorter time for implementation of embankment construction, reduce total settlement and avoid differential settlement, and are compatible with varied geological conditions. The bamboo grid and pile increase the stability of the embankment [8]. The piles as reinforcement can be designed from bamboo and concrete piles [8-11]. Besides, deep soil mixing can improve the bearing capacity of peat soil [12].

Generally, reinforcement used to support the embankment load is geosynthetic, but in this study, a combination of bamboo grid and concrete piles was used. Bamboo grid reinforcement on peat soil has been found quite effective in increasing the bearing capacity and reduce the settlement [13]. The bamboo grid can be used as the reinforcement on peat soil under the embankment load [14]. The reinforcement of bamboo grid can reduce the peat compression [15]. The reinforcement material needs local material from the bamboo grid and to increase the shear strength it needs a pile from concrete material. The full friction pile depends on the distance of center to center of the pile, the number of the pile, and the length of the pile [16]. Installation of piles on a concrete slab to support the embankment load is able to reduce the settlement and increase the modulus of subgrade reaction [10].

The time period of loading affects the stability and settlement of embankment [9]. Waruwu et al. [11] stated that the loading rate and duration of embankment influence the bearing capacity. Longer duration produces a higher bearing capacity than the single load does. This study aims to find the stages of the ideal load to maximize compression on peat soil and provide sufficient bearing capacity to support the embankment load. In addition to the influence of the peat compression, deflection of reinforcement needs to be researched, because a large deflection can cause embankment instability.

2. RESEARCH METHODS

This study used the peat soil as the research materials [13]. The physical properties of the peat soil have moisture content 945 %, bulk density 10.74 kN/m^3, organic content 96 %, fiber content 28 %, and ash content 4 %.

Fig. 1 shows an apparatus for the laboratory model test. The dimensions of the box test were 120 cm x 90 cm x 90 cm and has the height of the peat soil of 50 cm. The peat soil was prepared and compacted at the same field density.

The iron bars having dimensions of 19 mm x 19 mm x 40 mm, was used as the embankment model. The embankment load was given in stages, one stage, two stages, three stages, and six stages. The unit weight of iron bars (γ) was approximately 79.55 kN/m^3. One layer of the embankment load was given as high as h = 19 mm equivalent to the pressure (σ) of 1.51 kPa and a total of six layers of 9.07 kPa.

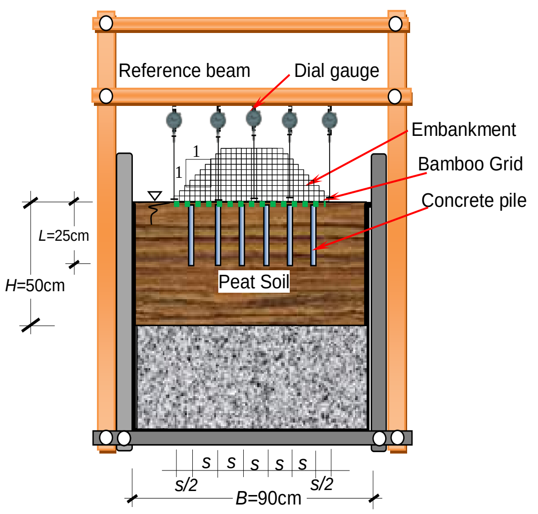

Fig. 1 The model test in the laboratory

Five dial gauges were used to read the vertical displacement due to the embankment load (Fig. 2). Two pile models were conducted in this study, monolithic and non-monolithic piles with bamboo grid, where the bamboo grid had an area of 60x30 cm^2, while the concrete piles had a diameter of 2 cm, length of 25 cm with a distance between center to center was 10 cm. The test was conducted on four different loading stage including a single loading of 9.07 kPa, two stages of 4.54 kPa, three stages of 3.02 kPa, and six stages of 1.51 kPa.

Fig. 2 Photographs of the model test

3. RESULTS AND DISCUSSIONS

The shear strength of peat soil can be determined by a shear test such as an unconfined compression test. Based on the results of the unconfined compression test, peat soil studied had undrained shear strength (C_u) of 6.15 kPa (Fig. 3). Peat soil is classified in very soft soils for C_u value < 12.5 kPa.

3.1 The Result of Embankment Loading Test

The results of the embankment loading test in both types of testing can be seen in Fig. 4 and Fig. 5, Both tests are distinguished by a relationship bamboo grid with the monolithic and non-monolithic pile.

The overall high compression occurs at the beginning of loading and followed by smaller compression changes. Settlement in the non-monolithic pile is greater than the monolithic pile.

Longer and monolithic piles generated smaller settlement [10].

Stages of load affects the rate of decline in peat soils. The excessive decrease can occur at lower load stages. More gradual loads look good for decreasing behavior because decreases that occur at each stage are relatively smaller.

The duration of loading shows the effect on compression behavior. Compression changes appear to decrease for a longer duration. Longer loading causes the peat soil layers to consolidate. Stage loading with a longer period produces a higher bearing capacity than direct load [11].

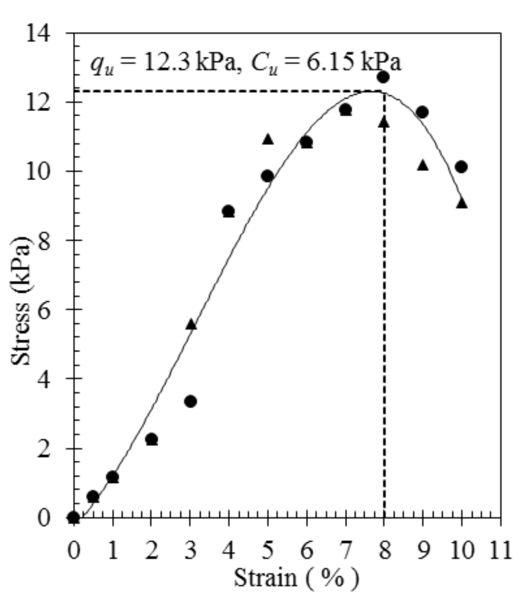

Fig. 3 The result of compression strength

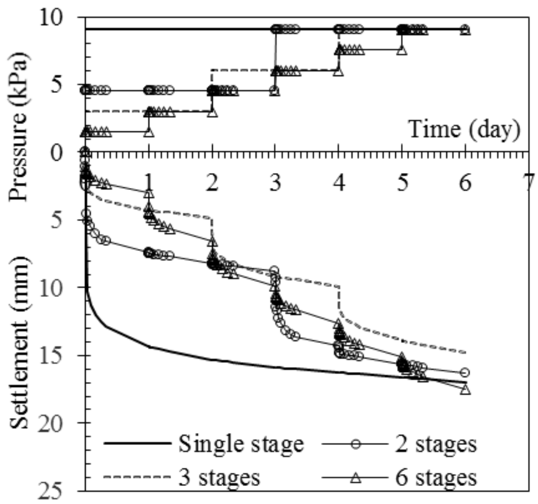

Fig. 4 The settlement in the center of the embankment for monolithic pile

3.2 The Effect of Loading Stage to Peat Compression

The relationship of pressure due to embankment load and the settlement are shown in Fig. 6 and Fig. 7. The settlement was influenced by the stages of the load and the connection of the pile to the bamboo grid. Loads with six stages show a greater settlement than others. This can be caused by each stage of the load only lasts for a day so the consolidation of the process is still not optimal.

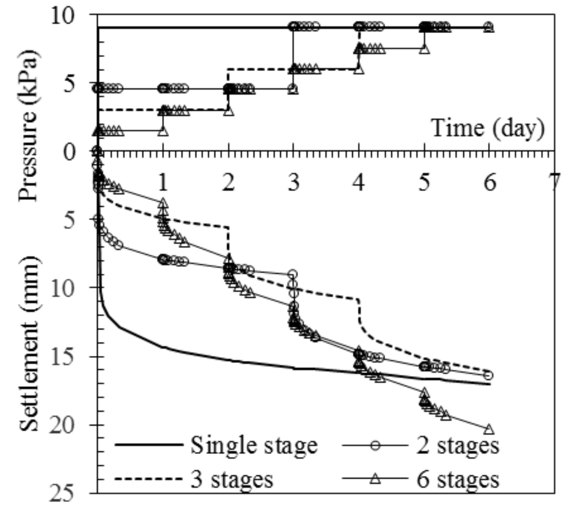

Fig. 5 The settlement in the center of the embankment for non-monolithic pile

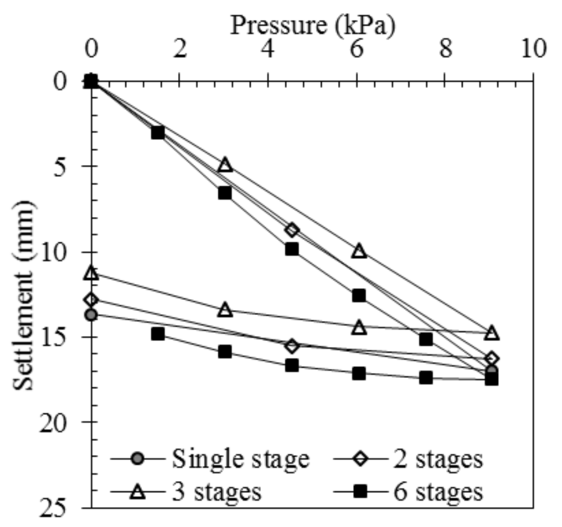

Fig. 6 The relationship between pressure and settlement for monolithic pile

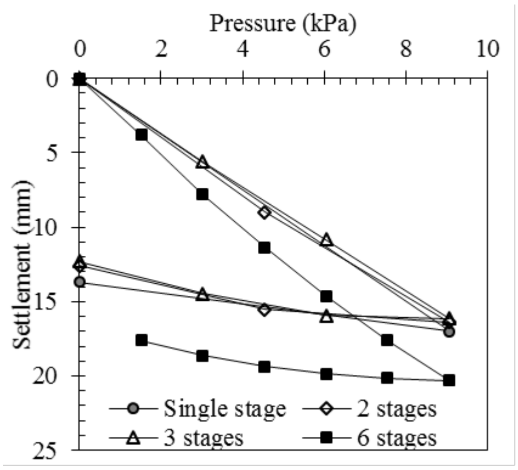

Fig. 7 The relationship between pressure and settlement for non-monolithic pile

Peat soil compression behavior due to the loading system can be seen in Fig. 8. Stages of the load appear to be influential at the time of loading, but the effect at the time of unloading looks insignificant. The embankment with loading-unloading affects compression behavior. The initial settlement is large in the loading stage, but the increment settlement gradually became smaller with time in the reloading stage [11].

Changes of compression appear to decrease at one stage, two stages and three stages load and increase at six stages for both monolith piles and non-monolith piles. Good results were obtained at three stages with a load duration of two days.

A good load stage influences the modulus of subgrade reaction (*k*), as shown in Fig. 9. The better reduction of compression can increase the modulus of subgrade reaction. Thus, if compression is reduced, the modulus of the subgrade reaction increases.

3.3 Effect of Loading Stage to Deflection

The deflection of bamboo grids reinforced by piles under embankment loads is shown in Fig. 10 and Fig. 11. The deflection of the monolith pile is higher than the monolith pile. Soil compressing behavior influences deflection. High compression shows greater deflection. The right load phase provides optimal compression and a relatively smaller deflection.

Stages of the load affect the deflection as seen in Fig. 12. In general, the three load stages show a good effect on the deflection for both monolithic and non-monolithic piles. The deflection of the bamboo grid reinforced by concrete piles at the three-stage load is smaller than the other load stages. The increase of embankment height on each stage resulted in decreasing settlement addition. Peat was compressed due to the embankment, thus settlement decreased [14].

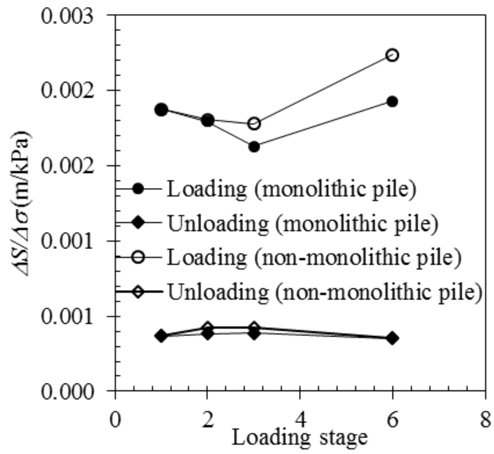

Fig. 8 The relationship between loading stage and $\Delta\sigma/\Delta S$

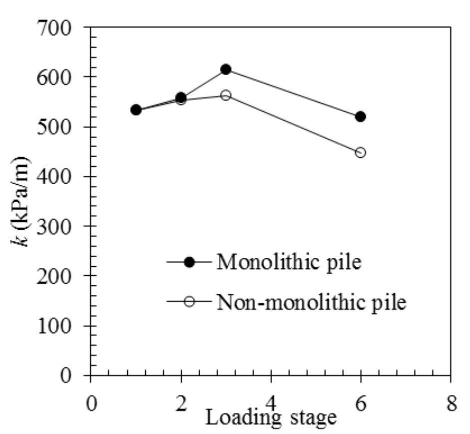

Fig. 9 The relationship between loading stage and *k*

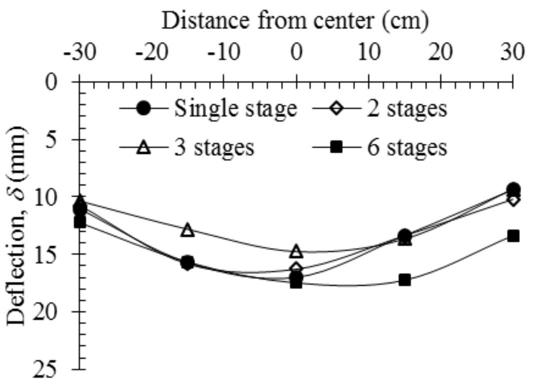

Fig. 10 The relationship between distance from center and deflection for monolithic pile

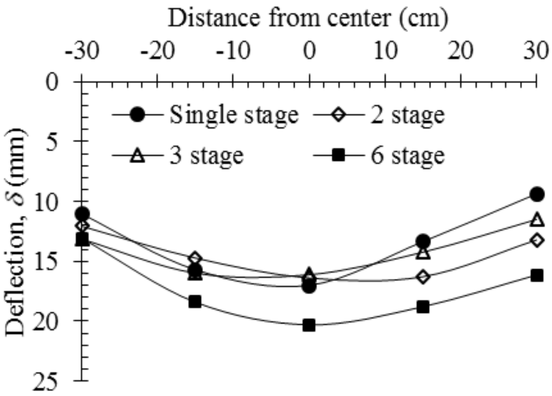

Fig. 11 The relationship between distance from center and deflection for non-monolithic pile

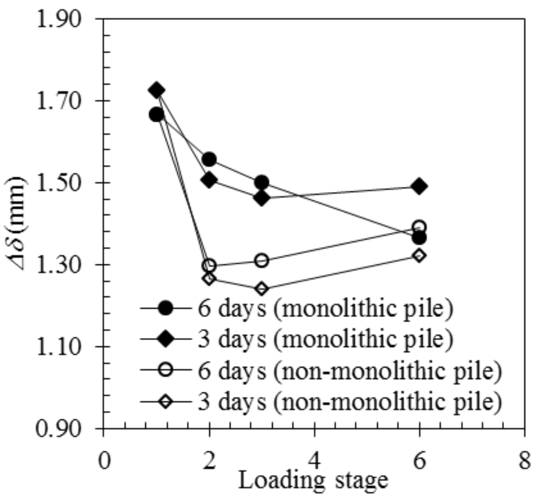

Fig. 12 The relationship between loading stage and $\Delta\delta$

4. CONCLUSION

Based on the results of the study, the conclusions are as follows:

1. Peat studied was classified into very soft soil types because it had a value of C_u = 6.15 kPa < 12.5 kPa. Bamboo grid reinforcement with concrete pile can increase the bearing capacity of peat soil so that the embankment load > C_u can still be applied.
2. Gradual load embankment is better in the process of reducing the peat compression because a single loading can lead to an excessive settlement due to lower bearing capacity.
3. Longer duration of load provides an opportunity for peat layers to consolidate so that the bearing capacity increases.
4. In this study, a good load stage is given in three stages with additional load every two days. Peat compression and deflection reinforcement are found to be smaller than the other stages.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Kalantari B., Civil Engineering Significant of Peat. Global Journal of Research in Engineering Civil And Structural Engineering, Vol. 13, No. 2, 2013, pp. 24-28.

[2] Mesri G., and Ajlouni M., Engineering Properties of Fibrous Peats. Journal of Geotechnical and Geoenvironmental Engineering, Vol. 133, No. 7, 2007, pp. 850-866.

[3] Waruwu A., Hardiyatmo H.C., and Rifa'i A., Compressive Behavior of Bagansiapiapi-Riau Peat in Indonesia, Electronic Journal of Geotechnical Engineering, Vol. 21, No. 16, 2016, pp. 5217-5227.

[4] Isobe Y., Shahin H.M., and Nakai T., Effectiveness of Reinforcement in Embankment Ground Subjected to Repeated Shear Deformation, International Journal of GEOMATE, Vol. 7, No. 2, 2014, pp. 1111-1116.

[5] Carchedi D.R., Monaghan J., and Parra J., Innovative Stabilization of Peat Soils for Railroad Foundation Using Rammed Aggregate Piers, in Proceedings of Sessions of Geoshanghai, Geotechnical Special Publication, No. 152, 2006, pp. 127-134.

[6] Rowe R.K., and Li A.L., Geosynthetic-Reinforced Embankments over Soft Foundations, Geosynthetics International, Vol.12, No.1, 2005, pp. 50-85.

[7] Liu H.L., Ng C.W., and Fei K., Performance of a Geogrid-Reinforced and Pile-Supported Highway Embankment over Soft Clay: Case Study, Journal of Geotechnical and Geoenvironmental Engineering, Vol.133, No.12, 2007, pp. 1483-1493.

[8] Maulana, Azwar, Susanti R.D., and Waruwu A., Potential of Bamboo Pile as Reinforcement of Peat Soil under Embankment, ARPN Journal of Engineering and Applied Sciences, Vol.13, No.1, 2018, pp. 52-56.

[9] Maulana M., Hanova Y., Waruwu A., and Putra E.R., Simplified Method for Prediction of Settlement in Bamboo Piles-Reinforced Peat under Embankment, Journal of Applied Engineering Science, Vol.17, No.1, 2019, pp.

35 – 42.
[10] Waruwu A., Hardiyatmo H.C., and Rifa'i A., Deflection Behavior of The Nailed Slab System-Supported Embankment on Peat Soil. Journal of Applied Engineering Science, Vol.15, No.4, 2017, pp. 556 – 563.
[11] Waruwu A., Hardiyatmo H.C., and Rifa'i A., Behavior of Nailed-Slab System on Peat Soil under Loading,) Proceedings of the 1nd Warmadewa University International Conference on Architecture and Civil Engineering, Bali, Indonesia, Vol.1, No.1, 2017, pp. 101-107.
[12] Dewi R., Borgan W., Zunita I., Yulindasari, and Iqbal M.M., Effect of Deep Soil Mixing to Increasing Bearing Capacity on Peat Soil, International Journal of GEOMATE, Vol.17, No.63, 2019, pp. 126-132.
[13] Waruwu A., Halim H., Nasution T., and Hanova, Y., Bamboo Grid Reinforcement on Peat Soil under Repeated Loading, Journal of Engineering and Applied Sciences, 2018, Vol.13, No.8, pp. 2190-2196.
[14] Waruwu A. Maulana, and Halim H., Settlement Estimation of Peat Reinforced with Bamboo Grid under Embankment, International Review of Civil Engineering (I.RE.C.E.), Vol.8, No.6, 2017, pp. 299-306.
[15] Waruwu A., Susanti R.D., and Buulolo J.A.P., Effect od Dynamic Loads on The Compressibility Behaviour of Peat Soil Reinforced by Bamboo Grids, Journal of Applied Engineering Science, Vol.17, No.2, 2019, pp. 157 – 162.
[16] Yudiawati Y., Mochtar I.B., and Mochtar N.E., Group Capacity and Efficiency of Full Friction Piles on Very Soft Soil, International Journal of GEOMATE, Vol. 16, No.57, 2019, pp. 201-208.